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Investigation Of Periodic Heat Transfer And Enhancement Using Nano Fluid Using CFD

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Abstract: **Many heat transfer applications such as steam generators in a boiler or air cooling coil of an air conditioner, can be modelled in a bank of tubes containing a fluid flowing at one temperature that is immersed in a second fluid in a cross flow at different temperature. CFD simulations are a useful tool for understanding flow and heat transfer principles as well as for modelling these types of geometries. Both the fluids considered in the present study are CUO Nano fluids, and flow is classified as laminar and steady with Reynolds number between 100-600.The mass flow rate of the cross flow and diameter has been varied (such as 0.05, 0.1, 0.15, 0.20, 0.25, 0.30 kg/sec and 0.8, 1.0.1.2 &1.4cm) and the models are used to predict the flow and temperature fields that result from convective heat transfer. Due to symmetry of the tube bank and the periodicity of the flow inherent in the tube bank geometry, only a portion of the geometry will be modelled and with symmetry applied to the outer boundaries. The inflow boundary will be redefined as a periodic zone and the outflow boundary is defined as the shadow. The various static pressures, velocities, and temperatures obtained are reported.**

In this present project tubes of different diameters and different mass flow rates and angle of arrangement are considered to examine the optimal flow distribution. Further the problem has been subjected to effect of materials used for tubes manufacturing on heat transfer rate. Materials considered are Cu and beryllium copper. Results emphasize the utilization of alloys in place of copper as tube material serves better heat transfer with most economical way.

Keywords: **Heat Transfer; Heat Exchanger; Nano Fluids; Mass Flow Rate; Periodic Flow; Nusselt Number & Reynolds Number;**

I. INTRODUCTION

Generally in any kind of heat exchanger the commonly used flowing fluid is water. But now here we are using Nano fluid (CUO). A Nano fluid is a fluid containing nanometre-sized particles, called nanoparticles. These fluids are engineered colloidal suspensions of nanoparticles in a base fluid. The nanoparticles used in Nano fluids are typically made of metals, oxides, carbides, or carbon nanotubes. Common base fluids include water, ethylene glycol and oil.

Nano fluids have novel properties that make them potentially useful in many applications in heat transfer including microelectronics, fuel cells , pharmaceutical processes, and hybrid –powered engines, engine cooling/vehicle thermal management, domestic refrigerator, chiller, heat exchangers in grinding, machining and in boiler flue gas Temperature reduction.They exhibit enhanced thermal conductivity and the convective heat transfer coefficient compared To the base fluid. Knowledge of the rheological behaviour of Nano fluids is found to be very critical in deciding their suitability for convective heat transfer.

Synthesis

Nano fluids are produced by several techniques they are,

1. Direct Evaporation (1 step),
2. Gas condensation/dispersion (2 step),
3. Chemical vapour condensation (1 step),
4. Chemical precipitation (1 step).

Several liquids including water, ethylene glycol, and oils have been used as base fluids. Nano-materials used so far in Nano fluid synthesis include metallic particles, oxide particles, carbon nanotubes, graphene Nano-flakes and ceramic particles

Applications

Nano fluids are primarily used as coolant in heat transfer equipment such as heat exchangers, electronic cooling system (such as flat plate) and radiators. Heat transfer over flat plate has been analysed by many researchers. Graphene based Nano fluid has been found to enhance polymerase chain reaction efficiency. Nano fluids in solar collectors are another application where Nano fluids are employed for their tenable optical properties.

Simulation& Need for CFD

Simulation

'Simulation' is the imitation of the operation of a real-world process or system over time. The act of simulating something first requires that a model to be developed. This model represents the key characteristics or behaviours of the selected physical system or abstract system or process. The model represents the system itself, whereas the simulation represents the operation of the system over time.

Simulation is an important feature in engineering system or any other system that involves many processes. For example in electrical engineering, delay lines may be used to simulate propagation delay and phase shift caused by an actual transmission line. Similarly, dummy loadsmay be used to simulate impedance without simulating propagation, and is used in situations where propagation is unwanted. A simulator may imitate only a few of the operations and functions of the unit it simulates. *Contrast with*: emulate. Most engineering simulations entail mathematical modelling and computer assisted investigation. There are many cases, however, where mathematical modelling is not reliable. Simulations of fluid dynamics problems often require both mathematical and physical simulations. In these cases the physical models require dynamic similitude. Physical and chemical simulations have also direct realistic uses, rather than research uses. For example in chemical engineering, process simulations are used to give the process parameters immediately used for operating chemical plants such as oil refineries.

Simulations can be categorised in different ways. Some of them are as follows:

1. Physical simulation refers to simulation in which physical objects are substituted for the real thing.

These physical objects are often chosen because they are smaller or cheaper than the actual object or system.

2. *Interactive simulation* is a special kind of physical simulation, often referred to as a *human in the loop*simulation, in which physical simulations include human operators, such as in a flight simulator or a driving simulator. Human in the loop simulations can include a computer simulation as a so-called *synthetic environment*. There are more different types of simulations according to the field or stream suiting for research. Here we are using engineering simulation with the help of Computational Fluid Dynamics (CFD) software.

Need for CFD

Conventional engineering analyses rely heavily on empirical correlations so it is not possible to obtain the results for specific flow and heat transfer patterns in heat exchanger of arbitrary geometry. Successful modeling of such process lies on quantifying the heat, mass and momentum transport phenomena. Today‟s design processes must be more accurate while minimizing development costs to compete in a world of economy. This forces engineering companies to take advantage of design tools which augment existing experience and empirical data while minimizing cost. One tool which excels under these conditions is CFD.

Computational Fluid Dynamics (CFD) makes it possible to solve numerically the flow and energy balances in complicated geometries. CFD simulates the physical flow, heat transfer, and combustion phenomena of solids, liquids, and gases and executing on high speed, large memory workstations. CFD has significant cost advantages when compared to physical modeling and field testing and also, provides additional insight into the physical phenomena being analyzed due to the availability of data that can be analyzed and the flexibility with which geometric changes can be studied. Effective heat transfer parameters estimated from CFD results matched theoretical model predictions reasonably well. Heat exchangers have been extensively researched both experimentally and numerically. However, most of the CFD simulation on heat exchangers was aimed at model validation.

Simulation phenomena in heat exchangers

Hilde VAN DER VYVER, Jaco DIRKER AND Jousa P. MEYER, who investigated the validation of a CFD model of a three dimensional Tube-in-Tube Heat Exchanger. The heat transfer coefficients and the friction factors were determined with CFD and compared to established correlations. The results showed the reasonable agreement with empirical correlation, while the trends were similar.

When applications.In analysis such as computational fluid dynamics (CFD), Nano fluids can be assumed to be single phase fluids. However, almost all of new academic paper uses two-phase assumption. Classical theory of single phase fluids can be applied, where physical properties of Nano fluids are taken as a function of properties of both constituents and their concentrations. An alternative approach simulates Nano fluids using a two-component model. The spreading of a Nano fluid droplet is enhanced by the solid-like ordering structure of nanoparticles assembled near the contact line by diffusion, which gives rise to a structural disjoining pressurein the vicinity of the contact line. However, such enhancement is not observed for small droplets with diameter of nanometre scale, because the wetting time scale is much smaller than the diffusion time scale.

II. LITERATURE SURVEY

INTRODUCTION

The thermo physical properties required for calculation of convective heat transfer coefficient and Nusselt number are thermal conductivity, viscosity, specific heat and density. Properties of single phase fluids are well documented and are available in heat transfer data books. But on the other hand the thermo physical properties of two phase fluids are not much available and needs to be measured by conducting experiments. Different researchers have elaborated experimental procedure for measurement of nanofluid properties.

Earlier studies reported that nanofluid properties vary with temperature and the particle volume concentration in the basefluid.

The thermal conductivities of two phase nanofluids are comparatively higher than those of base fluids. Properties of nanofluids can be advantageously altered to make them suitable particularly in heat transfer applications. Conventional heat transfer fluids can be replaced by nanofluids due to many advantages offered by the nanofluids.

Thermal conductivity is one of the important properties that influence heat transfer in nanofluids. Hence it is proposed to collect literature pertaining to the research work done on nanofluid properties and nanofluid heat transfer performance. The heat transfer Coefficient of nanofluids depends on fluid mass flow rate, type of flow that is whether the flow is laminar or turbulent and also on swirl in the flow, created by different inserts. Hence the literature collected is classified into five headings viz, literature on properties of nanofluids, literature on single phase fluids, literature on nanofluids in laminar and turbulent flow conditions and research papers on heat transfer augmentation using different types of inserts are collected, reviewed and presented as follows.

Working of nano fluid

A **nanofluid** is a fluid containing nanometer-sized particles, called nanoparticles. These fluids are engineered colloidal suspensions of nanoparticles in a base fluid. The nanoparticles used in nanofluids are typically made of metals, oxides, carbides, or carbon nanotubes. Common base fluids include water, ethylene glycol and oil.

Nanofluids have novel properties that make them potentially useful in many applications in heat transfer, including microelectronics, fuel cells, pharmaceutical processes, and hybrid-powered engines, engine cooling/vehicle thermal management, domestic refrigerator, chiller, heat exchanger,in grinding, machining and in boiler flue gas temperature reduction. They exhibit enhanced thermal conductivity and the convective heat transfer coefficient compared to the base fluid. Knowledge of the rheological behaviour of nanofluids is found to be very critical in deciding their suitability for convective heat transfer applications Nanofluids also have special acoustical properties and in ultrasonic fields display additional shear-wave reconversion of an incident compressional wave; the effect becomes more pronounced as concentration increases.

In analysis such as computational fluid dynamics (CFD), nanofluids can be assumed to be single phase fluids. However, almost all of new academic paper use two-phase assumption. Classical theory of single phase fluids can be applied, where physical properties of nanofluid is taken as a function of properties of both constituents and their concentrations. An alternative approach simulates nanofluids using a two-component model.

The spreading of a nanofluid droplet is enhanced by the solid-like ordering structure of nanoparticles assembled near the contact line by diffusion, which gives rise to a structural disjoining pressure in the vicinity of the contact line. However, such enhancement is not observed for small droplets with diameter of nanometer scale, because the wetting time scale is much smaller than the diffusion time scale.

LITERATURE REVIEW ON NANOFLUID PROPERTIES

A novel idea of two-phase fluid ie a liquid with nano particles present in it is conceived and this fluid mixture is expected to give high thermal conductivity. Nano particles of metals and metal oxides dispersed in any conventional heat transfer fluids show higher thermal conductivities when compared to the thermal conductivities of pure liquids. In the last 100 years, a number of theoretical and experimental studies were undertaken on the properties of liquid suspensions containing milli or micro sized particles.

Touloukian and Ho (1970) have proved experimentally that at room temperature, the thermal conductivity of Cu is 700 times more than that of water and 3000 fold more than that of engine oil. Hamilton and Crosser (1962) and Wasp (1977) have developed a thermal conductivity models for two-phase mixture based on their theoretical study. Sohn and Chen (1984) investigated thermal conductivity property of solid-fluid mixture at low velocity. At higher flow rate (higher peclet number), the thermal conductivity was observed to be increasing with increase in the shear rate. Masuda et al. (1993) studied the possibility of altering the properties of conventional heat transfer fluids by suspending submicron particles of water based Al203 and Ti02 and reported that the enhancement in the effective thermal conductivities are about 32% and 11%, respectively for the nanofluids of 4.3% volume concentration.

Choi (1995) is the first researcher who worked on nano particles at the Argonne National Laboratory, USA. He demonstrated that nanofluids exhibit an increased thermal conductivity compared to the host fluid. Eastman et al. (1997) observed that oxide nanoparticles, such as Al2O3 and CuO have excellent dispersion properties in water, oil and ethylene glycol and form stable suspensions. Wang et al. (1999) employed a steady state parallel plate method to measure the effective thermal conductivity of nanofluids. They tested two types of nanoparticles, Al2O3 and CuO, dispersed in water, engine oil, and ethylene glycol. Experimental results indicated higher thermal conductivities in fluid mixture than those of the base fluids and the measured thermal conductivity values are higher for nanofluids and the mixture formula under predicted experimental thermal conductivity of the above nanofluids.

Choi et al. (2001) noticed that engine oil of carbon nanotubes and with 1.0% volume concentration exhibited 160% increment in thermal conductivity. Das et al. (2003) employed temperature oscillation technique to measure thermal conductivity of water based Al2O3 and CuO nanofluids at different temperatures and observed a 200% to 400% increase in the thermal conductivity of nanofluids in the temperature range of 21^0C to 51^0C. Xue and Xu (2005) developed an effective thermal conductivity model for CuO/water and CuO/Ethylene glycol nanofluids taking into account the thermal conductivity of the solid and liquid, their relative volume fraction, particle size and interfacial properties.

Koo and Kleinstreuer (2005) studied conduction-convection heat transfer characteristics of water–ethylene/CuO nanofluids in micro channels and developed new models for thermal conductivity and viscosity including the effect of viscous dissipation. Murshed et al.

(2005) used spherical and cylindrical shaped TiO2 nanoparticles in water and measured the thermal conductivities applying hot wire method. Their results revealed that the thermal conductivity increased with increase in particle volume fraction. The particle size and shape also have a bearing on enhancement of thermal conductivity. The pH value and viscosity of the nanofluids are also characterized in their experimental work.

Liu et al. (2006) produced Cu nanoparticles of around 50–100 nm in diameter by chemical reduction method and nanofluid is prepared without adding a surfactant. In a 0.1% volume concentration Cu nanofluid, a 23.8% enhancement in the nanofluid thermal conductivity was reported by them. Wang et al (2006) measured thermal conductivities of Carbon Nano Tubes (CNT) in water, CuO in water, SiO2 in water, and CuO in ethylene glycol by transient hot-wire method and reported 11.3% improvement in the thermal conductivity of water-based CNT nanofluids with 0.01% volume concentration. The measured thermal conductivity found to be relatively higher than the thermal conductivity calculated using Hamilton–Crosser conductivity model. Beck et al. (2007) measured the thermal conductivity of ethylene glycol based alumina nanofluids in the temperature range of 298 to 411K using a transient hot wire method. Higher thermal conductivities were reported for all concentrations of nanofluids compared to the base liquid.

Casquillas et al. (2007) conducted experiments on thermal conductivity properties of ethylene glycol based nanofluids of carbon nanotubes at droplet level and found that nanotubes concentration has a strong effect on thermal conductivity. Chen et al. (2007) studied and measured shear viscosity of ethylene glycol-titania nanofluids upto 8% percent on particle weight basis and concluded that the shear viscosity of the nanofluids is a strong function of particle concentration and nanofluid temperature. Honga et al. (2007) worked on nanofluids containing carbon nanotubes and Fe2O3 particles and brought to light that the thermal conductivity of nanofluids can be improved by applying external magnetic field. He reasoned that the Fe2O3 particles align in the form of chains under applied magnetic Field and help to connect the nanotubes, which results in enhanced thermal conductivity.

Lee et al. (2008) estimated both thermal conductivities and viscosity properties of Al2O3 -water nanofluids and observed that both the properties are linearly increasing with increase in the nanoparticle concentration. Li et al. (2008) investigated the combined effects of PH variation and surfactant (Sodium Dodecyl Benzene Sulfonate) Cu nanofluids. They observed that the thermal conductivity of Cu/H2O nanofluids is more dependent on the weight fraction of nanoparticle, pH value of nanofluid and surfactant concentration. For a Cu nanoparticles of 0.01 % concentration with an optimal PH value and surfactant, highest thermal conductivity up to 10.7% was reported.

Suitable surfactant and optimum PH value play a role to improve thermal conductivity of nanofluids for heat transfer applications.

Mintsa et al. (2008) measured the effective thermal conductivity of water based alumina and copper oxide nanofluids. Their results have shown an increase in the effective thermal conductivity of nanofluids with an increase in particle volume concentration and with a decrease in particle size. It is also noticed that the relative increase in thermal conductivity was predominant at higher temperatures. Murshed et al. (2008) stated that thermal conductivity of nanofluids depends on factors like particle shape, size, interfacial layer, and temperature in addition to the particle volume fraction. Zhu et al.

(2008) studied the dispersion behavior and thermal conductivity of Al2O3/H2O Nanofluid by varying its pH values and Sodium Dodecyl Benzene Sulphonate concentration. The nanofluids exhibited better dispersion behavior when the surfactant is added in the Nanofluid.

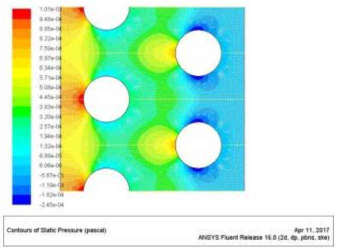
Lee et al. (2008) measured the effective viscosities and thermal conductivities of low concentration water-Al2O3 nanofluids. The viscosity of nanofluids decreased with increase in the temperature. But the measured thermal conductivity, on the other hand increased linearly with increase in nanofluids concentration. Namburu et al.

(2008) investigated the rheological property of copper oxide nanoparticles in ethylene glycol-water mixture base fluid by varying the nanoparticle concentrations from 0% to 6.12% in the temperature range from 35^0C to 50^0C. The nano fluid also exhibited Newtonian behavior in the concentration range tested. For a volume concentration of 6.12%, the viscosity of copper oxide nanofluid four fold higher than that of the base fluid at 35^0C.

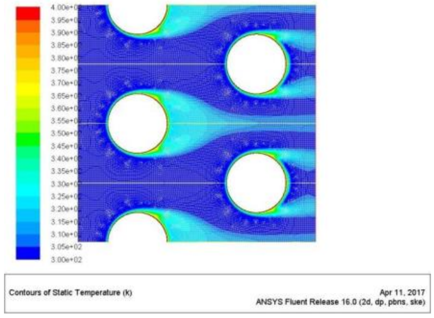
III. RESULTS

RESULTS OF THE PERIODIC HEAT TRANSFER

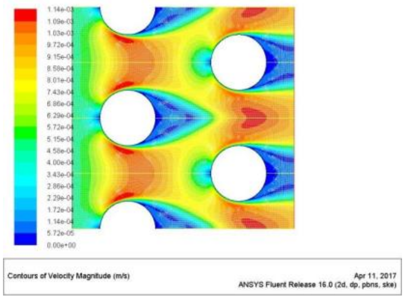
SIO2 as a working Fluid



Static Pressure Of periodic heat transfer with SIO2



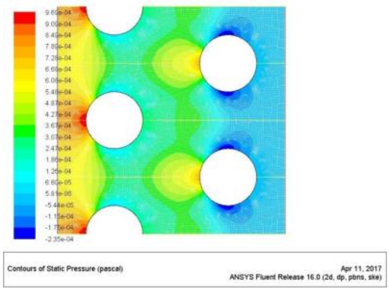
Static Temperature of the periodic heat transfer using SIO2



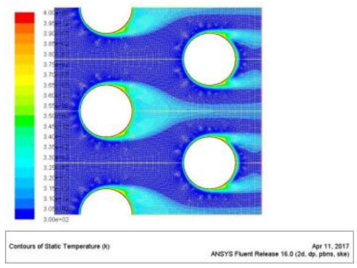
Velocity of the periodic heat transfer using SIO2

RESULTS OF THE PERIODIC HEAT TRANSFER USING CUO

CUO nano Fluid



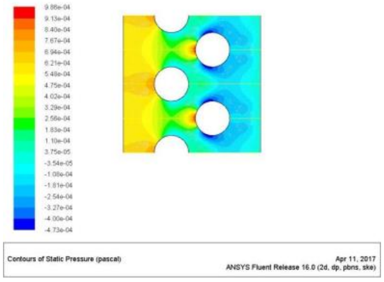
Static Pressure Of periodic heat transfer with CUO



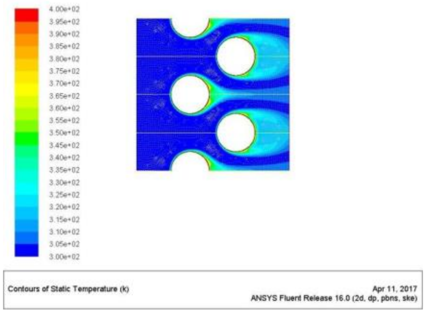
Static Temperature Of periodic heat transfer with CUO

RESULTS OF THE PERIODIC HEAT TRANSFER USING CUO

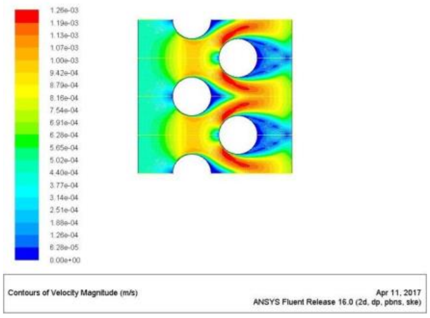
CUO nano Fluid With 60 degrees



Static Pressure Of periodic heat transfer with CUO with construction angle of 60 degrees



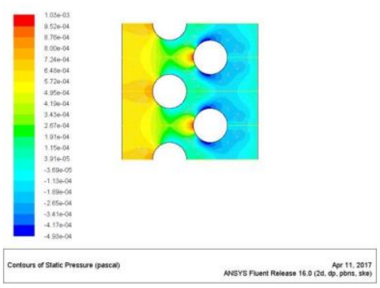
Static Temperature Of periodic heat transfer with CUO with construction angle of 60 degrees



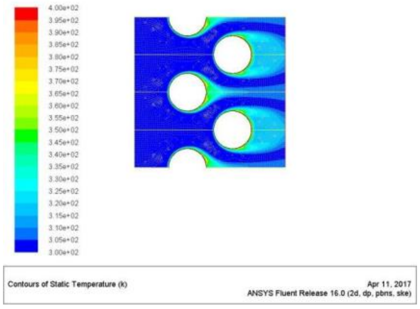
Velocity Magnitude Of periodic heat transfer with CUO with construction angle of 60 degrees

RESULTS OF THE PERIODIC HEAT TRANSFER USING CUO

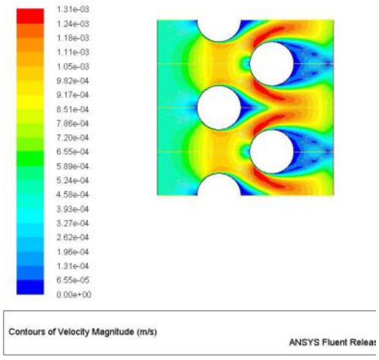
SIO2 nano Fluid With 60 degrees



Static Pressure Of periodic heat transfer with SIO2 with construction angle of 60 degrees



Static Pressure Of periodic heat transfer with SIO2with construction angle of 60 degrees



Velocity magnitude Of periodic heat transfer with SIO2 with construction angle of 60 degrees

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